

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: 83201826.1

(51) Int. Cl.³: **H 01 J 61/44**
C 09 K 11/475

(22) Date of filing: 21.12.83

(30) Priority: 30.12.82 NL 8205044

(43) Date of publication of application:
01.08.84 Bulletin 84/31

(84) Designated Contracting States:
AT BE CH DE FR GB IT LI NL SE

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(54) Low-pressure mercury vapour discharge lamp.

(57) A low-pressure mercury vapour discharge lamp having a very satisfactory colour rendition ($R(a,8) \geq 85$) and having a colour temperature of at least 3200 K and a colour point located on or near the Planckian locus. The lamp is provided with a luminescent layer comprising :

a. a luminescent alkaline earth metal halophosphate activated by Sb^{3+} or by Sb^{3+} and Mn^{2+}

b. a luminescent material activated by Eu^{2+} and having an emission maximum at 470-500 nm and a half-width value of at most 90 nm and

c. a luminescent rare earth metal metaborate activated by Ce^{3+} and Mn^{2+} and having a fundamental lattice $Ln(Mg,Zn,Cd)B_5O_{10}$, where Ln represents the elements Y, La and/or Gd, which borate has a red Mn^{2+} emission.

Preferably, the luminescent layer comprises :

d. a luminescent material activated by Tb^{3+} and having green Tb^{3+} emission.

With these lamps, the phenomenon of disruption of metamery is completely or substantially completely avoided. Furthermore, the lamps have a high luminous flux and a high maintenance of the luminous flux during the life.

Low-pressure mercury vapour discharge lamp.

The invention relates to a low-pressure mercury vapour discharge lamp having a very satisfactory colour rendition, having a colour temperature of the emitted white light of at least 3200 K and having a colour point (x_L, y_L) at or near the Planckian locus, which is provided with a gas-tight radiation-transparent envelope containing mercury and rare gas and with a luminescent layer containing a luminescent halophosphate and a luminescent material activated by bivalent europium.

The expression "a very satisfactory colour rendition" is to be understood in this description and the appended claims to mean that the average colour rendering index $R(a,8)$ (average value of the rendering indices of eight test colours, as defined by the Commission Internationale d'Eclairage: Publication CIE No. 13.2 (TC-3.2), 1974), has a value of at least 85.

The colour of visible radiation is characterized by the colour co-ordinates (x,y) which determine the colour point in the colour triangle (see Publication CIE No. 15 (E-1.3.1), 1971). Lamps for general illumination purposes should emit light which can be considered as "white". White radiation is found in the colour triangle at colour points located on the Planckian locus. This curve, which is also designated as the curve of the black body radiators and which is indicated hereinafter as the curve P, comprises the colour points of the radiation emitted by a completely black body at different temperatures (the so-called colour temperature). As the colour temperature of white radiation is higher, the x co-ordinate and - from a temperature of about 2500 K - also the y co-ordinate of the colour point have a smaller value. A given colour temperature is allotted not only to a given point on the curve P, but also to radiation having colour co-ordinates located

on a line intersecting the curve P at that point (see the said Publication CIE No. 15). If this radiation has a colour point near the curve P, this radiation is also considered as white light having that given colour temperature. In this description and the appended claims, the expression "a colour point near the curve P" is to be understood to mean that the distance of the colour point from the point on the curve P having the same colour temperature is at most 20 MPCD (Minimum Perceptible Colour Difference) is the unit of colour difference; see the publication of J.J. Rennilson in "Optical Spectra", October 1980, page 63.

A large number of embodiments of low-pressure mercury vapour discharge lamps which have been known for tens of years and are still frequently used contain a luminescent alkaline earth metal halophosphate activated by Sb^{3+} and Mn^{2+} . These lamps have the advantage that they are inexpensive and emit a satisfactorily high luminous flux. A great disadvantage of these lamps, however, is that their colour rendition leaves much to be desired. They generally have $R(a,8)$ values of the order of 50 to 60, and a $R(a,8)$ value of about 75 is only attained with lamps having a high colour temperature (for example, 5000 K), which is not yet considered to be a satisfactory colour rendition.

Lamps with which a very satisfactory colour rendition is attained have been known for a long time. These lamps are provided with special luminescent materials, i.e. a tin-activated red-luminescing material on the basis of strontium orthophosphate, frequently in combination with a blue-emitting halophosphate activated by Sb^{3+} , more particularly a strontium halophosphate of this kind. The said strontium orthophosphate luminesces in a very wide band which extends into the deep red. These known lamps have the disadvantage inherent to the use of the said strontium orthophosphate of a comparatively small luminous flux and of a poor maintenance of the luminous flux during the life of the lamp. It has been found that the last-mentioned

disadvantage is a serious limitation to the use of this material in practice with a higher load by the radiation emitted by the mercury discharge.

A lamp of the kind described in the opening
5 paragraph is known from German Patent Application 2,848,726. This lamp having a very satisfactory colour rendition contains, as the aforementioned lamp type, a red-luminescing tin-activated strontium orthophosphate and further a borate phosphate which is activated by bivalent europium
10 and has an emission band having a maximum at about 480 nm and a half-width value of about 85 nm. Preferably, a luminescent alkaline earth metal halophosphate is further used in the luminescent layer of this lamp. Due to the use of the luminescent strontium orthophosphate, this known
15 lamp again has the disadvantages of a comparatively small luminous flux and more particularly of a poor maintenance of the luminous flux during the life of the lamp.

A satisfactory colour rendition ($R(a,8)$ values of 80 - 85), a high luminous flux and a good maintenance
20 of the luminous flux, even with high loads, are obtained with lamps containing three luminescent materials emitting in three comparatively narrow bands (see Dutch Patent Specification 164,697 (PHN.7137)). In these lamps, there is the drawback of disruption of the metamerism of certain
25 colonies which, though of rare occurrence, is disturbing if particularly high requirements are imposed on the colour rendition. The colour impression of an object under the light of a lamp is then different from that under the light of a reference radiator having the same colour temperature.
30 The colours of two objects are generally designated as being metameric if these objects have a different reflection spectrum, but nevertheless give the same colour impression under a given kind of light, for example, day-light. If under another kind of light, for example of an incandescent
35 lamp, the colour impression of these objects is different, the metamerism is said to be disrupted.

The invention has for its object to provide low-pressure mercury vapour discharge lamps having a very

satisfactory colour rendition and more particularly a satisfactory colour rendition of a large number of colours, as a result of which the possibility is very small that metamery will be disrupted, whilst the said disadvantages of the known lamp are entirely or substantially entirely avoided.

For this purpose, according to the invention a low-pressure mercury vapour discharge lamp of the kind mentioned in the opening paragraph is characterized in that the luminescent layer comprises:

- a. at least one luminescent alkaline earth metal halophosphate activated by trivalent antimony or by trivalent antimony and bivalent manganese;
- b. at least one luminescent material activated by bivalent europium and having an emission maximum in the range of from 470 to 500 nm and a half-width value of the emission band of at most 90 nm, and
- c. a luminescent rare earth metal metaborate of monoclinic crystal structure which is activated by trivalent cerium and by bivalent manganese and whose fundamental lattice corresponds to the formula $\text{Ln}(\text{Mg}, \text{Zn}, \text{Cd})\text{B}_5\text{O}_{10}$, in which Ln is at least one of the elements yttrium, lanthanum and gadolinium and in which up to 20 mol.% of the B can be replaced by Al and/or Ga, which metaborate exhibits red Mn^{2+} emission.

Experiments leading to the invention have surprisingly shown that a very high value of $R(a,8)$ can also be obtained with an emission which has a much narrower band than that of the known luminescent strontium orthophosphate, but whose emission maximum lies at substantially the same location. It has been found that the emission rare earth metal metaborates activated by Ce^{3+} and Mn^{2+} is particularly suitable for this purpose. These metaborates are known per se and are further described in Dutch Patent Applicants 7905680 (PHN.9544) and 8100346 (PHN.9942). They have a fundamental lattice of monoclinic crystal structure according to the formula $\text{Ln}(\text{Mg}, \text{Zn}, \text{Cd})\text{B}_5\text{O}_{10}$. In this formula, Ln is at least one of the elements Y, La and

Gd. In the borate up to 20 mol.% of the B can be replaced by Al and/or Ga, which, like the choice of the elements Mg, Zn and/or Cd, has little influence on the luminescent properties. The Ce activator is built-in at an Ln location (and may even occupy all Ln locations) and absorbs the exciting radiation energy (mainly 254 nm in a low-pressure mercury vapour discharge lamp) and transmits it to the Mn activator which is built-in at an Mg (and/or Nz and/or Cd) location. The borate has a very efficient emission originating from Mn^{2+} in a band having a maximum at about 630 nm and a half-width value of about 80 nm.

A great advantage of the use of the metaborate in a lamp according to the invention is that also due to the comparatively small quantity of radiation energy in the deep red part of the spectrum, high luminous fluxes can be obtained. It has further been found that the metaborates have a very favourable lamp behaviour. This means that, at application in a lamp, they retain their favourable luminescent properties, and that they exhibit only a slight decrease in luminous flux during the life of the lamp. This is also the case with a comparatively high radiation load, for example, in lamps having a small diameter of, for example, 24 mm. It should be noted that the use of the known luminescent strontium orthophosphate has remained limited in practice generally to lamps having a large diameter (36 mm) because of the high decrease in luminous flux especially with a high load.

It has further been found that with the use of the metaborate in lamps, not only high to very high values for the general colour rendering index ($R(a,8)$ values of at least 85) can be obtained, but that also a large number of individual object colours can be reproduced very satisfactorily. This becomes manifest if the average colour rendition is determined on the basis of a series of 94 test colours as proposed by J.J. Opstelten in "Lighting Research and Technology", Vol. 12, No. 4, 1980, pp. 186-194. This group of 94 test colours comprises both unsaturated and highly saturated colours and has colour points more or less

regularly distributed in the colour space. With lamps according to the invention, a value of this average colour rendering index $R(a,94)$ of at least 85 is obtained. A great advantage of the lamps according to the invention inherent to the high value of $R(a,94)$ is that errors in the colour rendition due to the fact that metamerism is disrupted are entirely or substantially entirely avoided.

In order to obtain such high values of $R(a,8)$ and $R(a,94)$, in a lamp according to the invention, the metaborate (the material c) has to be combined with a material activated by bivalent europium and having an emission maximum in the range of from 470 to 500 nm and a half-width value of the emission band of at most 90 nm (the material b), and with at least one luminescent halophosphate (the material a) of the group of the alkaline earth metal halophosphates activated by Sb or by Sb and Mn. An advantage of the blue-luminescing materials b is that they can be very efficient and that due to the comparatively narrow band of the emission, they substantially do not emit radiation in the short-wave part of the spectrum in which the eye sensitivity is substantially zero. Furthermore, the materials activated by bivalent europium generally have the advantage that they absorb at least in part the blue mercury line emitted by the mercury discharge. The halophosphates a have the advantage of an efficient emission having a broad band and excellently complementing the spectrum of the radiation emitted by the materials b and c.

The halophosphates used as material a are luminescent materials which have been known for a long time. They have the crystal structure of the mineral apatite and, as is known, their composition generally deviates slightly from the stoichiometric formula $M_{10}(PO_4)_6X_2$, (M = alkaline earth metal, X is halogen). As alkaline earth metal use is mainly made of calcium and/or strontium. If only Sb is used as an activator, a broad-band emission is obtained in the blue part of the spectrum. If Mn is also added as an activator, white-luminescing materials can be obtained

whose colour temperature is mainly determined by the Sb : Mn ratio. As halogen, fluorine and/or chlorine is generally used in the halophosphate. With a given F : Cl ratio, the colour point of the radiation emitted by the halophosphate lies on or substantially on the Planckian locus. If this ratio assumes lower values, the colour point is shifted to locations below the Planckian locus, whereas with higher values of F : Cl the colour point is shifted to locations above this curve. Thus, for example, yellow-luminescing halophosphates are also known.

Lamps according to the invention are preferred, which are characterized in that the luminescent halophosphate a is a calcium halophosphate activated by antimony and manganese and having a colour temperature of the emitted radiation of at least 2900 K. In fact, when compared with the strontium halophosphates, the calcium halophosphates have a smaller decrease in luminous flux during the life of the lamp even with a high load, for example, in lamps having a small diameter. An additional advantage of calcium halophosphates is that they are frequently used and are inexpensive and can be obtained with any desired colour temperature from about 2900 K. A desired colour temperature can be obtained not only by a suitable choice of the Sb : Mn ratio, but also by the use of mixtures of two halophosphates having different colour temperatures. A halophosphate having a very high colour temperature can also be obtained by mixing a blue-luminescing Sb-activated halophosphate with a white-luminescing Sb- and Mn-activated halophosphate. This substantially continuous possibility of choosing the colour temperature of the halophosphate renders an optimization of lamps according to the invention quite possible, which will be explained further hereinafter.

Preferably, a lamp according to the invention is characterized in that the luminescent layer contains a material (d) activated by trivalent terbium which has a green Tb^{3+} emission. The use of the Tb-activated luminescent materials affords the advantage that a larger colour

temperature range becomes possible for the lamps according to the invention. In general, such a material is necessary if lamps having a comparatively low colour temperature (of from 3200 K to about 4200 K) should be obtained with the said high values of $R(a,8)$ and $R(a,94)$. It has also been found that for higher colour temperatures the optimum results are generally obtained if a material having a Tb-emission is used. The Tb-emission provides an additional degree of freedom, as a result of which an optimization becomes more readily possible. Furthermore, the use of Tb-activated luminescent materials has the advantage that such green-luminescing materials are generally very efficient and contribute significantly to the luminous flux emitted by the lamp. As material d use may be made of, for example, the known Tb-activated cerium magnesium aluminates (see Dutch Patent Specification 160,869 (PHN 6604)) or cerium aluminates (see Dutch Patent Application 7216765 (PHN.6654)), which aluminates have a hexagonal crystal structure related to magnetoplumbite. A Ce- and Tb-activated metaborate is also very suitable, whose fundamental lattice is the same as that of the metaborates having red Mn^{2+} emission (the material c). In these known borates (see the aforementioned Dutch Patent Applications 7905680 and 8100346) Ce and Tb are built-in at an Ln location and the exciting radiation is absorbed by the cerium and transmitted to the terbium activator. The said Tb-activated materials all have a very favourable lamp behaviour and especially a good maintenance of the high luminous flux during the operation of the lamps.

An embodiment of a lamp according to the invention, which is preferred, is characterized in that the luminescent metaborate c is further activated by trivalent terbium, the metaborate c being at the same time the material d and satisfying the formula

$(Y, La, Gd)_{1-x-y} Ce_x Tb_y (Mn, Zn, Cd)_{1-p} Mn_p B_5 O_{10}$,
in which $0.01 \leq x \leq 1-y$

$0.01 \leq y \leq 0.75$

$0.01 \leq p \leq 0.30$, and in which up to 20 mol.% of

the B can be replaced by Al and/or Ga. This lamp has the great advantage that both the red Mn^{2+} emission and the green Tb^{3+} emission are supplied by one luminescent material. Thus, the manufacture of the lamps is of course simplified because a smaller number of luminescent materials are required. In these lamps, the desired relative red Mn^{2+} contribution and green Tb^{3+} contribution can be adjusted by varying the concentrations of Mn and Tb in the metaborate. As will appear hereinafter, the value of these relative contributions is dependent upon the desired colour point of the lamp and upon the luminescent materials a and b used. It is possible to manufacture and to optimize one luminescent metaborate, whose ratio between the Mn^{2+} emission and the Tb^{3+} emission has a value near the average desired value and to carry out in a given lamp application a correction (dependent upon the desired colour point) with either a small quantity of a red- or deep red-luminescing metaborate or with a small quantity of a green or deep green-luminescing Tb-activated material. It is of course also possible to optimize two luminescent metaborates with which lamps of any desired colour temperature may be realized by the use of suitable mixtures of these two materials.

In a lamp according to the invention, whose luminescent layer comprises as constituents the materials a, b, c and, as the case may be, d, the choice of one of these materials is determined not only by the desired colour point, but also by the choice of the remaining luminescent materials. Thus, it has been found that the choice of a specific blue-luminescing material (b) activated by Eu^{2+} for a lamp having a given colour temperature leads to a given group of halophosphates (a) that can possibly be used, whereby any other halophosphates have to be excluded if they would lead to lamps having too low values (< 85) of $R(a, 8)$ and $R(a, 94)$. If a specific choice is then made from the group of the halophosphates that can possibly be used, it is found that the lamp having the desired colour temperature, apart from the colour rendition

requirements imposed, can be obtained only with the use of a given series of mixtures of the luminescent materials c and d. The series of mixtures that can possibly be used of the materials c and d is generally limited further by the requirement that the lamp must have $R(a,8)$ and $R(a,94)$ values of at least 85.

For further explanation, reference is made to Figure 1 of the drawing. This Figure represents a part of the colour triangle in the (x,y) colour co-ordinate plane. The x-co-ordinate is plotted on the abscissa and the y-co-ordinate of the colour point is plotted on the ordinate. Of the sides of the colour triangle itself, on which the colour points of monochromatic radiation are located, only the part denoted by M is visible in Figure 1. The Figure shows for colour temperatures of from about 2500 K to about 8000 K the Planckian locus denoted by P. The dotted curves designated by +20 MPCD and -20 MPCD comprise the colour points of radiation which are located at a distance of 20 MPCD above and below the curve P, respectively. Colour points of constant colour temperature are located on lines intersecting the curve P. A number of these lines are drawn and indicated with the associated colour temperature: 2500 K, 3000 K ... 8000 K. Figure 1 further indicates in numerals and letters the colour point of a number of lamps and luminescent materials. In this description and the appended claims, the colour point of a luminescent material is to be understood to mean the colour point of a low-pressure mercury vapour discharge lamp having a length of about 120 cm and an inner diameter of about 24 mm and operated with a power consumption of 36 W, which lamp is provided with a luminescent layer which comprises only the said luminescent material, the chosen value of the layer thickness being an optimum as regards the relative luminous flux. Therefore, for the colour points of luminescent materials the influence of the visible radiation emitted by a low-pressure mercury vapour discharge lamp itself is always taken into account. It should be noted that the luminous efficiency of the

luminescent material still slightly influences the location of the colour point. The use of the luminescent materials in low-pressure mercury vapour discharge lamps other than the said 36 W-type will generally lead to only a very small shift of the colour points with respect to those shown herein.

In Figure 1, c denotes the colour point of a red-luminescing metaborate activated by Ce and Mn and having the colour co-ordinates $(x;y) = (0.546; 0.301)$.

d denotes the colour point of a green-luminescing Tb-activated material. The points designated by the reference numerals 17, 18 and 20 are the colour points of three luminescent materials activated by bivalent europium and having an emission maximum between 470 and 500 nm. The graph shown in Figure 1 further indicates the colour points of a number of conventional calcium halophosphates emitting white light and having different colour temperatures (the points 7, 8, 9 and 15), of blue-luminescing Sb-activated calcium halophosphate (point 19) and of yellow-luminescing Sb- and Mn-activated calcium fluorophosphate (point 10). Other colour temperatures are possible by varying the Sb : Mn ratio, but also by using mixtures of halophosphates. Thus, 01, 02, 03 and 04 in Figure 1 indicate the colour points of mixtures of the materials 15 and 9, and 05, 06, 07 and 08 indicate the colour points of mixtures of the materials 15 and 19. The following Table 1 indicates the colour co-ordinates and the colour temperatures of the said halophosphates.

Table 1

	material	x	y	T(K)
5	7	0.437	0.397	2945
	8	0.399	0.380	3565
	9	0.368	0.373	4335
	15	0.312	0.332	6505
	19	0.216	0.273	> 20000
10	01	0.357	0.365	4640
	02	0.346	0.357	5000
	03	0.334	0.349	5420
	04	0.323	0.341	5900
	05	0.293	0.321	7800
15	06	0.274	0.309	9650
	07	0.255	0.297	12500
	08	0.236	0.285	18200
	10	0.410	0.434	3730

20 With the use of two luminescent materials in a lamp, all the colour points located on the connection line of the colour points of the two chosen materials can be attained. By way of example, in Figure 1 the connection line K of the colour points of the halophosphate 9 and

25 of the blue-luminescing material 18 is represented. The location of the colour points lying on the line K of lamps only provided with the materials 9 and 18 is invariably determined by the relative quantum contributions of the materials 9 and 18 to the radiation emitted by the lamp.

30 The distance of the colour point of the lamp from the point 9 divided by the distance between the points 9 and 18 is in fact proportional to the relative quantum contribution of the material 18 and to the relative luminous flux (lm/W) supplied by the material 18 if it is provided

35 in the lamp as the only luminescent material and is further inversely proportional to the y-co-ordinate of the colour point of the material 18. An analogous relation applies to the distance of the colour point from the point 18.

With the use of given materials 9 and 18 (for which the relative luminous flux and the y-co-ordinate are consequently fixed), only the relative quantum contributions therefore determine the colour point of the lamp. For these materials 9 and 18, the required relative quantum contributions are then known if a given colour point of the lamp is desired. These quantum contributions in the first instance are a measure of the quantity of the materials 9 and 18 to be used. When determining these quantities, the quantum efficiency and the absorption of exciting radiation of the materials 9 and 18 and moreover factors, such as, for example, the grain size of the materials used, should be taken into account. If luminescent layers are used which do not form a homogeneous mixture of the materials 9 and 18, especially if the materials are applied in separate juxtaposed layers, great differences may of course occur in absorption of exciting radiation by the materials 9 and 18. As a result, with the same relative quantum contributions, the relative quantities of the materials 9 and 18 may greatly differ from those with the use of homogeneous mixtures. In general, it will be desirable to check for a few test lamps whether the desired relative quantum contributions are reached with the choice of the quantities of the luminescent materials.

For illustration, the colour point $\underline{u}$ of a lamp having a colour temperature of 6000 K and a colour point on the curve P is indicated in Figure 1. This lamp can be obtained, for example, by the use of a luminescent layer comprising the blue-luminescing material 18 and the halophosphate 9. If the luminescent layer has added to it only the material $\underline{c}$ (Ce- and Mn-activated rare earth metal metaborate having a colour point $x = 0.546$ and $y = 0.301$), the relative quantum contributions of the materials 18 and 9 are fixed. In fact, the latter then have to be chosen so that with these materials the colour point $\underline{u}'$ is reached, $\underline{u}'$ being located on the connection line between $\underline{c}$ and $\underline{u}$. By a suitable choice of the relative quantum contributions of the material $\underline{c}$ and of the combination $\underline{u}'$, the colour

point u is reached. If the luminescent layer has added to it as the fourth constituent a green-luminescing terbium-activated material, for example, the Ce- and Tb-activated metaborate d having a colour point $x = 0.324$ and $y = 0.535$, it is found that the ratio of the relative quantum contributions of the materials d and c (d : c) is determined by the chosen ratio of the relative quantum contributions of the materials 18 and 9 (18 : 9). As the ratio (18 : 9) increases, the ratio (d : c) increases in such manner that the colour point obtained with d and c is located on the connection line of the colour point obtained with 18 and 9 and the point u. The largest ratio (d : c) with which it is possible to reach the colour point u is indicated in Figure 1 by the point h. In this case, however, the luminescent layer does not contain halophosphate 9. Although for all the ratios (d : c) with colour points between the points c and h located on the connection line L of c and d the colour point u can be obtained by combination with the materials 18 and 9, in general not every combination will lead to a lamp having $R(a,8)$ and $R(a,94)$ values of at least 85. Especially in those cases in which the contribution of the halophosphate 9 is equal to zero or is very small, the lamp will not satisfy the requirements imposed. The range of (d : c) ratios with which lamps according to the invention are obtained can be determined with a few test lamps and appears to comprise, for example, the ratios lying between the points c and k. The presence of such a range between c and k offers the advantage that optimization of the lamp is quite possible.

Moreover, by way of further example, Figure 1 indicates the colour point y of a lamp having a colour temperature of 4000 K and a colour point located on the curve P. This lamp can be obtained with the blue-luminescing material 17 and the halophosphate 7, which two materials together yield colour points located on the connection line N of 17 and 7. If as a further luminescent material only the material c is used, the colour point y can be reached with the lamp if the relative quantum contributions

of 7 and 17 are chosen so that with the materials 7 and 17 the point v' located on the connection line between v and c is attained. At this comparatively low colour temperature of 4000 K, however, a Tb-activated green-luminescing material, such as d , appears to be necessary to obtain the desired high $R(a,8)$ and $R(a,94)$ values. The largest relative quantum contribution of the material d with which it is possible to reach the colour point v , is that contribution which in combination with only the material c leads to the colour point e on the line L. In this case, however, the lamp does not contain halophosphate 7, and it also appears that the colour rendition requirements are not satisfied. The range of $(d : c)$ ratios within which this is the case and in which optimization of the lamp is possible, can be determined and proves to comprise, for example, the ratios lying between the points f and g .

A very advantageous embodiment of a lamp according to the invention is characterized in that the material b is a luminescent aluminate which is activated by bivalent europium and corresponds to the formula $Sr_{1-p}Eu_pAl_qO_{1/2(q+1)}$, in which up to 25 mol. % of the strontium can be replaced by calcium and in which $0.001 \leq p \leq 0.10$ and $2 \leq q \leq 5$, which aluminate has its emission maximum at 485 - 495 nm and has a half-width value of 55 - 75 nm.

The colour point of the radiation emitted by such an aluminate is indicated in Figure 1 by the point 17 and has the co-ordinates $x = 0.152$ and $y = 0.360$. The said luminescent strontium aluminates are described more fully in Dutch Patent Application 8201943 (PHN.10.347). They completely satisfy the condition imposed of an emission having a comparatively narrow band with a maximum in the range of from 470 to 500 nm. Furthermore, these materials are very efficiently luminescing materials which can be subjected even for a long time to high loads in lamps and then exhibit only a very small decrease in luminous flux.

Especially such a lamp containing strontium aluminate is preferred, which has a colour point of the emitted radiation (x_L, y_L) and a colour temperature T , T being

chosen in the range $3200\text{ K} \leq T \leq 7500\text{ K}$, which lamp is characterized in that the halophosphate a is a calcium halophosphate activated by Sb or by Sb and Mn and having a colour point of the emitted radiation (x_H, y_H) , where x_H lies in the range $0.210 \leq x_H \leq 0.440$ and the combination (T, x_H) lies in the region of the graph of Figure 2 indicated by ABCDEFG. In the graph of Figure 2, the co-ordinate of the calcium halophosphate to be used (x_H) is plotted on the abscissa. The colour temperature T (in K) of the lamp according to the invention is plotted on the right-hand part of the ordinate. The x-co-ordinate of the lamp (x_L) is plotted on the lefthand part of the ordinate, whereby it should be noted that the given x_L values only correspond to the T values indicated beside them at colour points (x_L, y_L) on the curve P. It now appears from Figure 2, which halophosphates are preferably used in accordance with the invention if a lamp containing the aforementioned blue-luminescing strontium aluminate and having a desired colour temperature T should be manufactured. Examinations have shown that with all the (T, x_H) combinations lying within the region enclosed by the line ABCDEFG and the x_H axis, lamps can be obtained having $R(a, 8)$ and $R(a, 94)$ values of at least 85. The region ABCDEFG also comprises the possible combinations (T, x_H) for lamps having a colour point located near the curve P. If only colour points (x_L, y_L) on or substantially on the curve P itself are considered, especially the region not shaded in grey between the lines indicated by 1 and 2 applies. The grey region between the lines 1 and KDE also applies especially to lamps according to the invention which have a colour point located below the curve P (down to -20 MPCD). For lamps having a colour point located above the curve P (up to +20 MPCD), possible combinations (T, x_H) are also found in the region shaded in grey between the lines ABH and 1 and also in the grey region between the lines GF and 2.

It has been found that optimum results are obtained with lamps according to the invention which contain

the strontium aluminate described above and which have a colour temperature of at least 3700 K and a colour point on or substantially on the curve P, if the combination (T, x_H) lies in the region between the lines 3 and 4 of the graph of Figure 2. In this region (the line 4 partly coincides with the line 2) lamps can generally be obtained which have $R(a,8)$ and $R(a,94)$ values of at least 90.

If with reference to Figure 2, a lamp according to the invention having a given colour temperature T should be manufactured, it can be read from this Figure, which calcium halophosphates in combination with the blue-luminescing strontium aluminate are preferred. As appears from the explanation with respect to Figure 1 of the use of a given halophosphate, the contributions of the luminescent materials $\underline{c}$ and $\underline{d}$ to be used cannot be chosen quite freely. By way of example, Figure 3 indicates for a number of practical calcium halophosphates, which relative contributions of the materials $\underline{c}$ and $\underline{d}$ are possible for lamps containing strontium aluminate and having a colour point on the curve P. In the graph of Figure 3, the x-co-ordinate $x(\underline{c}, \underline{d})$ of the colour points that can be attained with the materials $\underline{c}$ and $\underline{d}$ only is plotted on the abscissa. As in Figure 2, the colour temperature T (in K) is plotted on the righthand part and the x-co-ordinate x_L of the lamp according to the invention on the lefthand part of the ordinate. The loops denoted by the numerals 7, 9, 02, 04, 05, 06 and 08 limit the regions within which lamps according to the invention having $R(a,8)$ and $R(a,94)$ values of at least 85 are obtained with the respective calcium halophosphates 7, 9, 02 08 from Table 1. The halophosphates are stated here in the order of succession of decreasing x_H value. The loops partly overlap each other, the loop of the halophosphate of the highest x_H value being found in the lefthand upper part of the graph. As the x_H value is smaller, the relevant loop is found further displaced to the righthand lower part of the graph. For halophosphates having an x_H value lying between those of the halophosphates mentioned herein, intermediate loops are

found.

By way of example, for the lamp designated in Figure 1 by y, having a colour temperature $T = 4000$ K and provided with the halophosphate 7 and a blue-luminescing strontium aluminate, the range of $x(\underline{c}, \underline{d})$ is indicated by the points f and g which correspond to f and g in Figure 1. It also appears from Figure 3 that for a lamp having a given colour temperature T , there can generally be made a choice from several possible calcium halophosphates. It is then mostly advantageous choose that halophosphate whose loop in Figure 3 has the largest cross-section with the line through the chosen point T on the ordinate and parallel to the $x(\underline{c}, \underline{d})$ axis. In fact, the manufacture of the lamp is then less critical because slight deviations in the envisaged relative quantum contributions of the luminescent materials are not seriously disturbing. Thus, it appears from Figure 3 that for the 4000 K lamp the halophosphate 7 is a favourable choice. The choice for this lamp of the halophosphate 9 is less favourable (the line f-g only has a small cross-section with the loop 9). The halophosphates 02 and certainly 04 are again more advantageous in this respect.

Another very advantageous embodiment of a lamp according to the invention is characterized in that the material b is a luminescent aluminate which is activated by bivalent europium and corresponds to the formula $\text{Ba}_{1-p}\text{Eu}_p\text{Al}_q\text{O}_{1/2 + 1}$, in which up to 25 mol.% of the barium can be replaced by strontium and in which $0.005 \leq p \leq 0.25$ and $5 \leq q \leq 10$, which aluminate has its emission maximum at 475-485 nm and has a half-width value of 70-90 nm. The colour point of the radiation emitted by such a barium aluminate is indicated in Figure 1 by the point 20 and has the co-ordinates $x = 0.161$ and $y = 0.242$. These luminescent barium aluminates are described more fully in Dutch Patent Application 8105739 (PHN.10220). These aluminates also completely satisfy the condition of an emission having a comparatively narrow band emission with a maximum in the range of from 470 to 500 nm. These materials are very

efficiently luminescing materials which have a high maintenance of the luminous flux during the life of the lamp and which can be subjected to high loads in lamps.

5 Especially such a lamp containing barium aluminate is preferred, which has a colour point of the emitted radiation (x_L, y_L) and a colour temperature T , T being chosen to lie in the range $3200\text{ K} \leq T \leq 7500\text{ K}$, which lamp is characterized in that the halophosphate a is a calcium halophosphate activated by Sb or by Sb and Mn and having
10 a colour point of the emitted radiation (x_H, y_H) , x_H lying in the range $0.210 \leq x_H \leq 0.440$ and the combination (T, x_H) lying in the region of the graph of Figure 4 designated by ABCDEF. Figure 4 is analogous to Figure 2 and shows in a graph the x-co-ordinates of the calcium halophosphates
15 preferably to be used if lamps containing the aforementioned luminescent barium aluminate are manufactured. It has again been found that with all the (T, x_H) combinations lying within the region enclosed by the line ABCDEF and the x_H axis, lamps having $R(a, 8)$ and $R(a, 94)$ values of at least 85 can be obtained. If only lamps having a colour
20 point (x_L, y_L) on or substantially on the curve P are considered, more particularly the region not shaded in grey below the line denoted by 1 applies. The grey region between the lines 1 and ABC also applies to lamps according
25 to the invention having a colour point above the curve P (up to +20 MPCD) and the grey region between the lines 1 and DE also applies to lamps having a colour point below the curve P (down to -20 MPCD).

30 The optimum results are obtained with lamps according to the invention which contain the luminescent barium aluminate described above and which have a colour temperature of at least 4800 K and a colour point on or substantially on the curve P if the combination (T, x_H) lies in the region between the lines 2 and 3 of the graph
35 of Figure 4. In fact, in this region lamps can be obtained having $R(a, 8)$ and $R(a, 94)$ values of at least 90. In Figure 5 there is indicated in the same manner as in Figure 3 for a few practical calcium halophosphates, which relative

contributions of the materials c and d are possible for lamps containing barium aluminate and having a colour point on the curve P. The loops designated by 7, 9 and 03 apply to the halophosphates 7, 9 and 03, respectively, from Table 1. The loop 7 (broken line) overlaps for a large part the loop 9 (full line). For the halophosphates with x_H smaller than about 0.370 (halophosphate 9 has $x_H = 0.368$), the loops prove to coincide substantially, except for the range of lamps having a very high T ($T > 7000$ K) so that the choice of the halophosphate to be used is then not very critical. The region applying to the halophosphate 03 comprises besides the region indicated by the dotted line 03 substantially the whole region applying to halophosphate 9.

A further advantageous embodiment of a lamp according to the invention is characterized in that the material b is a luminescent borate phosphate activated by bivalent europium and corresponding to the formula

$m(\text{Sr}_{1-x-y-p}\text{Ba}_x\text{Ca}_y\text{Eu}_p)\text{O} \cdot (1-n)\text{P}_2\text{O}_5 \cdot n(\text{B}_2\text{O}_3)$, in which

$$\begin{aligned} 0 &\leq x \leq 0.5 \\ 0 &\leq y \leq 0.2 \\ 0.001 &\leq p \leq 0.15 \\ 1.75 &\leq m \leq 2.30 \\ 0.05 &\leq n \leq 0.23, \end{aligned}$$

which borate phosphate has its emission maximum at 470-485 nm and has a half-width value of 80 - 90 nm. The colour point of the radiation emitted by such a borate phosphate is indicated in Figure 1 by the point 18 and has the coordinates $x = 0.191$ and $y = 0.308$. These luminescent borate phosphates are known from the aforementioned German Patent Application 2848726. They have a tetragonal crystal structure and are found to be efficiently luminescing materials having an emission which is very suitable for lamps according to the invention.

Especially such a lamp containing borate phosphate is preferred, which has a colour point of the emitted radiation (x_L, y_L) and a colour temperature T, T being chosen to lie in the range $3200 \text{ K} \leq T \leq 7500 \text{ K}$, which lamp is cha-

racterized in that the halophosphate a is a calcium halophosphate activated by Sb or by Sb and Mn and having a colour point of the emitted radiation (x_H, y_H) , x_H lying in the range $0.210 \leq x_H \leq 0.440$ and the combination (T, x_H) lying in the region of the graph of Figure 6 designated by ABCDEF. Figure 6 is again analogous to Figure 2 and indicates the x co-ordinates of the calcium halophosphates to be preferably used for lamps containing the aforementioned luminescent borate phosphate. With combinations (T, x_H) lying within the region enclosed by the line ABCDEF and the x_H axis, lamps can be obtained having $R(a, 8)$ and $R(a, 94)$ values of at least 85. Especially the region not shaded in grey between the lines denoted by 1 and 2 applies to lamps having a colour point (x_L, y_L) on or substantially on the curve P. The grey region between the lines 1 and BGH and at the same time the grey region below the line 2 apply also to lamps according to the invention having a colour point located above the curve P (up to +20 MPCD). The grey region between the lines 1 and KDE also applies to lamps having a colour point located below the curve P (down to -20 MPCD).

The optimum results are obtained with lamps according to the invention which contain the aforementioned luminescent borate phosphate and have a colour temperature of at least 4300 K and a colour point on or substantially on the curve P if the combination (T, x_H) lies in the region between the lines 3 and 4 of the graph of Figure 6. In this case, lamps can be obtained having $R(a, 8)$ and $R(a, 94)$ values of at least 90. In Figure 7 there is indicated in the same manner as in Figure 3 for a number of practical halophosphates, i.e. the materials 7, 02, 15, 06 and 08 from Table 1, which relative contributions of the materials c and d are possible for lamps containing borate phosphate and having a colour point on the curve P.

Embodiments of lamps according to the invention will now be described more fully with reference to Figure 8, which shows diagrammatically and in cross-section a low-pressure mercury vapour discharge lamp, and with reference

to practical compositions of luminescent layers and measurements on lamps provided with these layers.

In Figure 8, reference numeral 1 designates the glass wall of a low-pressure mercury vapour discharge lamp according to the invention. At the ends of the lamp there are provided electrodes 2 and 3 between which the discharge takes place during operation of the lamp. The lamp is provided with rare gas, which serves as ignition gas, and further with a small quantity of mercury. The lamp has a length of 120 cm and an inner diameter of 24 mm and is intended to consume during operation a power of 36 W. The wall 1 is coated on the inner side with a luminescent layer 4 which comprises the luminescent materials a, b, c and, as the case may be, d. The layer 4 may be applied to the wall 1 in a conventional manner, for example, by means of a suspension comprising the luminescent materials.

The following embodiments relate to lamps of the kind described with reference to Figure 8 (36 W-type). These lamps were provided with a luminescent layer comprising a homogeneous mixture of a blue-luminescing material activated by bivalent europium, a luminescent halophosphate and a luminescent metaborate. All these materials originated from production lots or from larger test lots. For the blue-luminescing material, a choice was made from a strontium aluminate (SAE) of the kind described above and indicated in Figure 1 by the colour point 17, a barium aluminate (BAE) of the kind indicated in Figure 1 by the colour point 20, and a borate phosphate (SBP) comparable with the material indicated in Figure 1 by the colour point 18. As halophosphates three white-luminescing materials were used (halo 8, halo 9 and halo 15), which are analogous to the aforementioned materials having colour points 8, 9 and 15, respectively, in Figure 1, and a yellow-luminescing halophosphate (halo 10). The luminescent metaborates used (borate 1 to borate 6 inclusive) contain both Mn and Tb so that both the red Mn^{2+} emission and the green Tb^{3+} emission can be supplied by each of these materials. The formulae of the materials used are given in the following

Table 2.

Table 2

Phosphor	formula
5 SAE	$\text{Sr}_{0.98}\text{Eu}_{0.02}\text{Al}_{3.5}\text{O}_{6.25}$
BAE	$\text{Ba}_{0.95}\text{Eu}_{0.05}\text{Al}_{8.10}\text{O}_{13.15}$
SBP	$2(\text{Sr}_{0.94}\text{Eu}_{0.06})\cdot 0.833\text{P}_2\text{O}_5\cdot 0.167\text{B}_2\text{O}_3$
halo 8	$\text{Ca}_{9.454}\text{Cd}_{0.04}(\text{PO}_4)_6\text{F}_{1.69}\text{Cl}_{0.288}:\text{Sb}_{0.09}\text{Mn}_{0.256}$
10 halo 9	$\text{Ca}_{9.524}\text{Cd}_{0.04}(\text{PO}_4)_6\text{F}_{1.73}\text{Cl}_{0.226}:\text{Sb}_{0.09}\text{Mn}_{0.186}$
halo 15	$\text{Ca}_{9.641}\text{Cd}_{0.025}(\text{PO}_4)_6\text{F}_{1.584}\text{Cl}_{0.36}:\text{Sb}_{0.09}\text{Mn}_{0.084}$
halo 10	$\text{Ca}_{9.53}(\text{PO}_4)_6\text{F}_2:\text{Sb}_{0.12}\text{Mn}_{0.35}$
borate 1	$\text{Ce}_{0.2}\text{Gd}_{0.6}\text{Tb}_{0.2}\text{Mg}_{0.96}\text{Mn}_{0.04}\text{B}_5\text{O}_{10}$
15 borate 2	$\text{Ce}_{0.2}\text{Gd}_{0.6}\text{Tb}_{0.2}\text{Mg}_{0.9575}\text{Mn}_{0.0425}\text{B}_5\text{O}_{10}$
borate 3	$\text{Ce}_{0.2}\text{Gd}_{0.6}\text{Tb}_{0.2}\text{Mg}_{0.94}\text{Mn}_{0.06}\text{B}_5\text{O}_{10}$
borate 4	$\text{Ce}_{0.2}\text{Gd}_{0.6}\text{Tb}_{0.2}\text{Mg}_{0.93}\text{Mn}_{0.07}\text{B}_5\text{O}_{10}$
borate 5	$\text{Ce}_{0.2}\text{Gd}_{0.7}\text{Tb}_{0.1}\text{Mg}_{0.92}\text{Mn}_{0.08}\text{B}_5\text{O}_{10}$
20 borate 6	$\text{Ce}_{0.2}\text{Gd}_{0.6}\text{Tb}_{0.2}\text{Mg}_{0.88}\text{Mn}_{0.12}\text{B}_5\text{O}_{10}$

In order to determine the properties of these materials, lamps were first manufactured (36 W) which were provided with only the relevant luminescent material. The relative luminous flux η (in lm/W) and the colour point (x,y) were measured. The results are indicated in Table 3.

Table 3

	Phosphor	η	x	y
	SAE	82	0.151	0.364
5	BAE	66	0.161	0.238
	SBP	77	0.191	0.309
	halo 8	86	0.402	0.389
	halo 9	82	0.368	0.379
	halo 15	72	0.312	0.339
10	halo 10	90	0.410	0.434
	borate 1	68	0.452	0.404
	borate 2	66	0.454	0.404
	borate 3	54	0.488	0.377
	borate 4	50	0.497	0.363
15	borate 5	46	0.512	0.350
	borate 6	40	0.530	0.333

Example 1

A lamp was provided with a luminescent layer
 20 consisting of a mixture of

11 % by weight of BAE

25 % by weight of halo 9

64 % by weight of borate 2.

The mass of the luminescent layer in the lamp was 4.05 g.

25 The colour temperature T (in K), the colour point (x,y)
 the deviation of the colour point from the curve P (ΔP in
 MPCD), the colour rendering indices R(a,8) and R(a,94) and
 the relative luminous flux (η in lm/W) were measured on
 the lamp:

30 $T = 3790 \text{ K}$, $x = 0.386$, $y = 0.370$ $\Delta P = -14 \text{ MPCD}$,
 $\eta = 70 \text{ lm/W}$, $R(a,8) = 89$ and $R(a,94) = 87$.

Example 2

A lamp was provided with a luminescent layer
 (5,52 g) consisting of a mixture of

35 7.1 % by weight of SBP

28.6 % by weight of halo 15,

64,3 % by weight of borate 1.

The parameters of this lamp were :

$T = 4170 \text{ K}, \quad x = 0.373, \quad y = 0.371, \quad \Delta P = 0,$
 $\eta = 70 \text{ lm/W}, \quad R(a,8) = 90 \quad \text{and} \quad R(a,94) = 87.$

After 100, 1000 and 2000 operating hours, the
relative luminous flux was 70, 67 and 65 lm/W, respectively.

Example 3

A lamp was provided with a luminescent layer
(4,5 g) consisting of a mixture of
22.2 % by weight of SAE
35.8 % by weight of halo 8
42 % by weight of borate 5.

The parameters of this lamp were :

$T = 3870 \text{ K}, \quad x = 0.384, \quad y = 0.372, \quad \Delta P = -9 \text{ MPCD},$
 $\eta = 64 \text{ lm/W}, \quad R(a,8) = 93 \quad \text{and} \quad R(a,94) = 90.$

Example 4

A lamp was provided with a luminescent layer
(4.1 g) consisting of a mixture of
17 % by weight of SAE
34 % by weight of halo 9
49 % by weight of borate 4.

The parameters of this lamp were :

$T = 3640 \text{ K}, \quad x = 0.392, \quad y = 0.370, \quad \Delta P = -18 \text{ MPCD},$
 $\eta = 63 \text{ lm/W} \quad R(a,8) = 93 \quad \text{and} \quad R(a,94) = 90.$

Example 5

A lamp was provided with a luminescent layer
(4.25 g) consisting of a mixture of
26.8 % by weight of SAE
30.4 % by weight of halo 10
42.8 % by weight of borate 6.

The parameters of this lamp were :

$T = 4100 \text{ K}, \quad x = 0.377, \quad y = 0.378, \quad \Delta P = +5 \text{ MPCD},$
 $\eta = 63 \text{ lm/W}, \quad R(a,8) = 94 \quad \text{and} \quad R(a,94) = 92.$

Example 6

A lamp was provided with a luminescent layer
(4.25 g) consisting of a mixture of
17 % by weight of SAE
37 % by weight of halo 15
46 % by weight of borate 3.

The parameters of this lamp were :

$T = 4560 \text{ K}$, $x = 0.359$, $y = 0.365$, $\Delta P = +4 \text{ MPCD}$,
 $\eta = 64 \text{ lm/W}$, $R(a,8) = 92$ and $R(a,94) = 89$.

Example 7

5 A lamp was provided with a luminescent layer
(4.75 g) consisting of a mixture of
17.1 % by weight of SAE
42.7 % by weight of halo 15
40.3 % by weight of borate 3.

10 The parameters of this lamp were :

$T = 4900 \text{ K}$, $x = 0.349$, $y = 0.363$, $\Delta P = +12 \text{ MPCD}$,
 $\eta = 66 \text{ lm/W}$, $R(a,8) = 95$ and $R(a,94) = 94$.

The spectral energy distribution of the emitted radiation
of this lamp is shown in Figure 9. In this Figure, the
15 wave-length λ in nm is plotted on the abscissa; the emit-
ted radiation energy E (in arbitrary units) per wave-length
interval of 5 nm is plotted on the ordinate.

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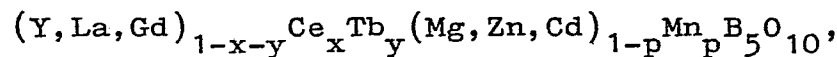
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CLAIM 1

1. A low-pressure mercury vapour discharge lamp having a very satisfactory colour rendition, having a colour temperature of the emitted white light of at least 3200 K and having a colour point (x_L, y_L) on or near the Planckian locus, which is provided with a gas-tight radiation-transparent envelope containing mercury and rare gas and with a luminescent layer containing a luminescent halophosphate and a luminescent material activated by bivalent europium, characterized in that the luminescent layer comprises :
- 5
- a. at least one luminescent alkaline earth metal halophosphate activated by trivalent antimony or by trivalent antimony and by bivalent manganese,
- b. at least one luminescent material activated by bivalent europium and having an emission maximum in the range from 470 to 500 nm and a half-width value of the emission band of at most 90 nm, and
- 15
- c. a luminescent rare earth metal metaborate activated by trivalent cerium and by bivalent manganese and having a monoclinic crystal structure, whose fundamental lattice corresponds to the formula $\text{Ln}(\text{Mg}, \text{Zn}, \text{Cd})\text{B}_5\text{O}_{10}$, in which Ln is at least one of the elements yttrium, lanthanum and gadolinium and in which up to 20 mol.% of the B can be replaced by Al and/or Ga, which metaborate exhibits red Mn^{2+} emission.
- 20
2. A lamp as claimed in Claim 1, characterized in that the luminescent halophosphate a is a calcium halophosphate activated by antimony and manganese and having a colour temperature of the emitted radiation of at least 2900 K.
- 30
3. A lamp as claimed in Claim 1 or 2, characterized in that the luminescent layer contains a luminescent material (d) activated by trivalent terbium, which has

green Tb³⁺ emission.

4. A lamp as claimed in Claim 3, characterized in that the luminescent metaborate c is further activated by trivalent terbium, the metaborate c being at the same time the material d and satisfying the formula



in which $0.01 \leq x \leq 1-y$

$$0.01 \leq y \leq 0.75$$

$$0.01 \leq p \leq 0.30 \text{ and in which up to 20 mol.\% of}$$

the B can be replaced by Al and/or Ga.

5. A lamp as claimed in Claim 1, 2, 3 or 4, characterized in that the material b is a luminescent aluminate activated by bivalent europium and corresponding to the formula $Sr_{1-p} Eu_p Al O_{1\frac{1}{2}q+1}$, in which up to 25 mol.% of the strontium can be replaced by calcium and in which $0.001 \leq p \leq 0.10$ and $2 \leq q \leq 5$, which aluminate has its emission maximum at 485 - 495 nm and has a half-width value of 55 - 75 nm.

6. A lamp as claimed in Claim 5, which has a colour point of the emitted radiation (x_L, y_L) and a colour temperature T, T being chosen to lie in the range $3200 K \leq T \leq 7500 K$, characterized in that the halophosphate a is a calcium halophosphate activated by Sb or by Sb and Mn and having a colour point of the emitted radiation (x_H, y_H), x_H lying in the range $0.210 \leq x_H \leq 0.440$ and the combination (T, x_H) lying in the region of the graph of Figure 2 designated by ABCDEFG.

7. A lamp as claimed in Claim 6, having a colour temperature of at least 3700 K and a colour point on or substantially on the Planckian locus, characterized in that the combination (T, x_H) lies in the region between the lines 3 and 4 of the graph of Figure 2.

8. A lamp as claimed in Claim 1, 2, 3 or 4, characterized in that the material b is a luminescent aluminate activated by bivalent europium and corresponding to the formula $Ba_{1-p} Eu_p Al O_{1\frac{1}{2}q+1}$, in which the barium can be replaced up to 25 mol.% by strontium and in which $0.005 \leq p \leq 0.25$ and $5 \leq q \leq 10$, which aluminate has its

emission maximum at 475 - 485 nm and has a half-width value of 70 - 90 nm.

9. A lamp as claimed in Claim 8, which has a colour point of the emitted radiation (x_L, y_L) and a colour temperature T, T being chosen to lie in the range $3200 \text{ K} \leq T \leq 7500 \text{ K}$, characterized in that the halophosphate a is a calcium halophosphate activated by Sb or by Sb and Mn and having a colour point of the emitted radiation (x_H, y_H), x_H lying in the range $0.210 \leq x_H \leq 0.440$ and the combination (T, x_H) lying in the region of the graph of Figure 4 designated by ABCDEF.

10. A lamp as claimed in Claim 9 having a colour temperature of at least 4800 K and having a colour point on or substantially on the Planckian locus, characterized in that the combination (T, x_H) lies in the region between the lines 2 and 3 of the graph of Figure 4.

11. A lamp as claimed in Claim 1, 2, 3 or 4, characterized in that the material b is a luminescent borate phosphate activated by bivalent europium and corresponding to the formula

$m(\text{Sr}_{1-x-y-p}\text{Ba}_x\text{Ca}_y\text{Eu}_p\text{O}) \cdot (1-n)\text{P}_2\text{O}_5 \cdot n\text{B}_2\text{O}_3$, in which

$$0 \leq x \leq 0.5$$

$$0 \leq y \leq 0.2$$

$$0.001 \leq p \leq 0.15$$

$$1.75 \leq m \leq 2.30$$

$$0.05 \leq n \leq 0.23,$$

which borate phosphate has its emission maximum at 470-485 nm and has a half-width value of 80-90 nm.

12. A lamp as claimed in Claim 11, which has a colour point of the emitted radiation (x_L, y_L) and a colour temperature T, T being chosen to lie in the range $3200 \text{ K} \leq T \leq 7500 \text{ K}$, characterized in that the halophosphate a is a calcium halophosphate activated by Sb or by Sb and Mn and having a colour point of the emitted radiation (x_H, y_H), x_H lying in the range $0.210 \leq x_H \leq 0.440$ and the combination (T, x_H) lying in the region of the graph of Figure 6 designated by ABCDEF.

13. A lamp as claimed in Claim 12 having a colour

temperature of at least 4300 K and having a colour point located on or substantially on the Planckian locus, characterized in that the combination (T, x_H) lies in the region between the lines 3 and 4 of the graph of Figure 6.

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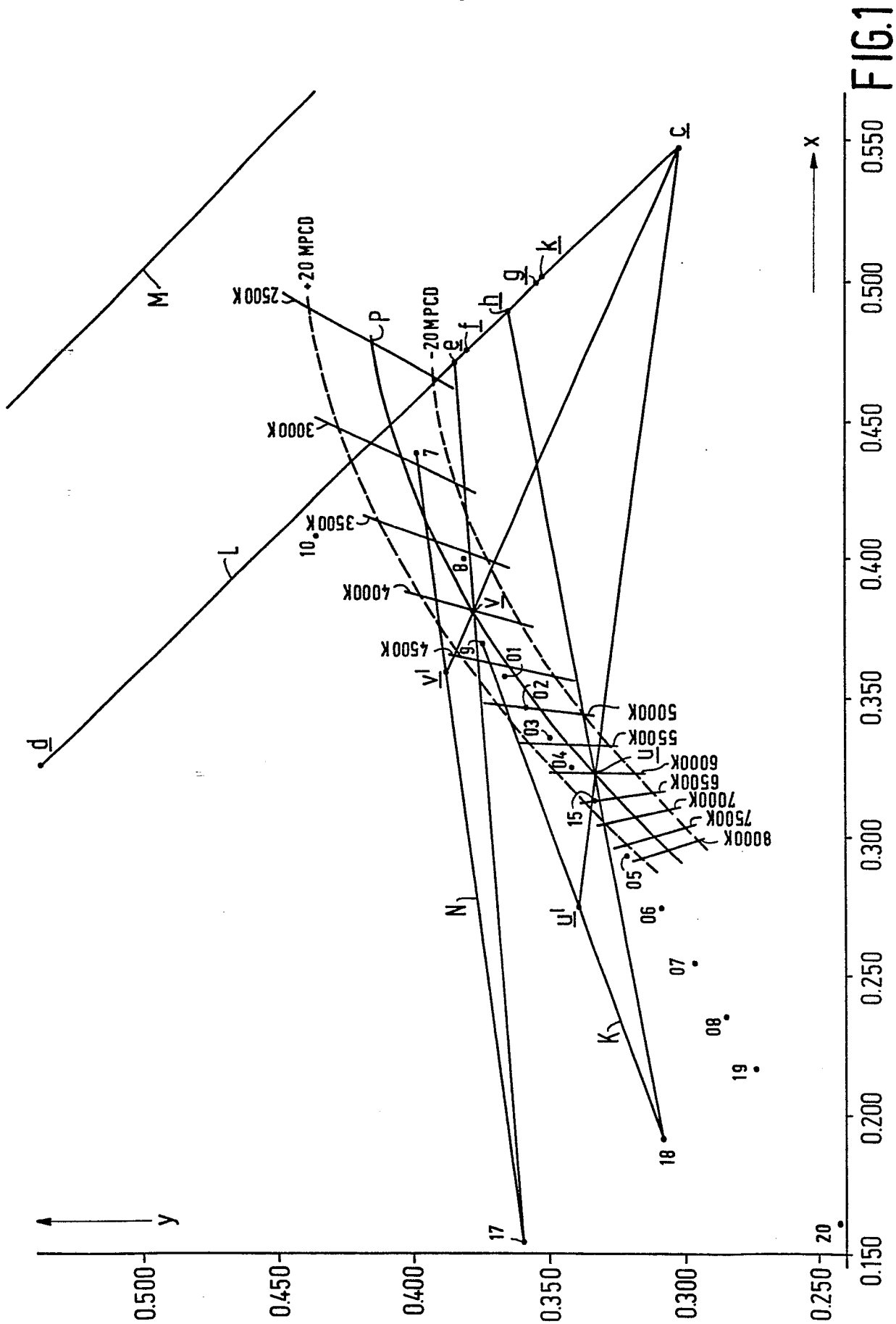
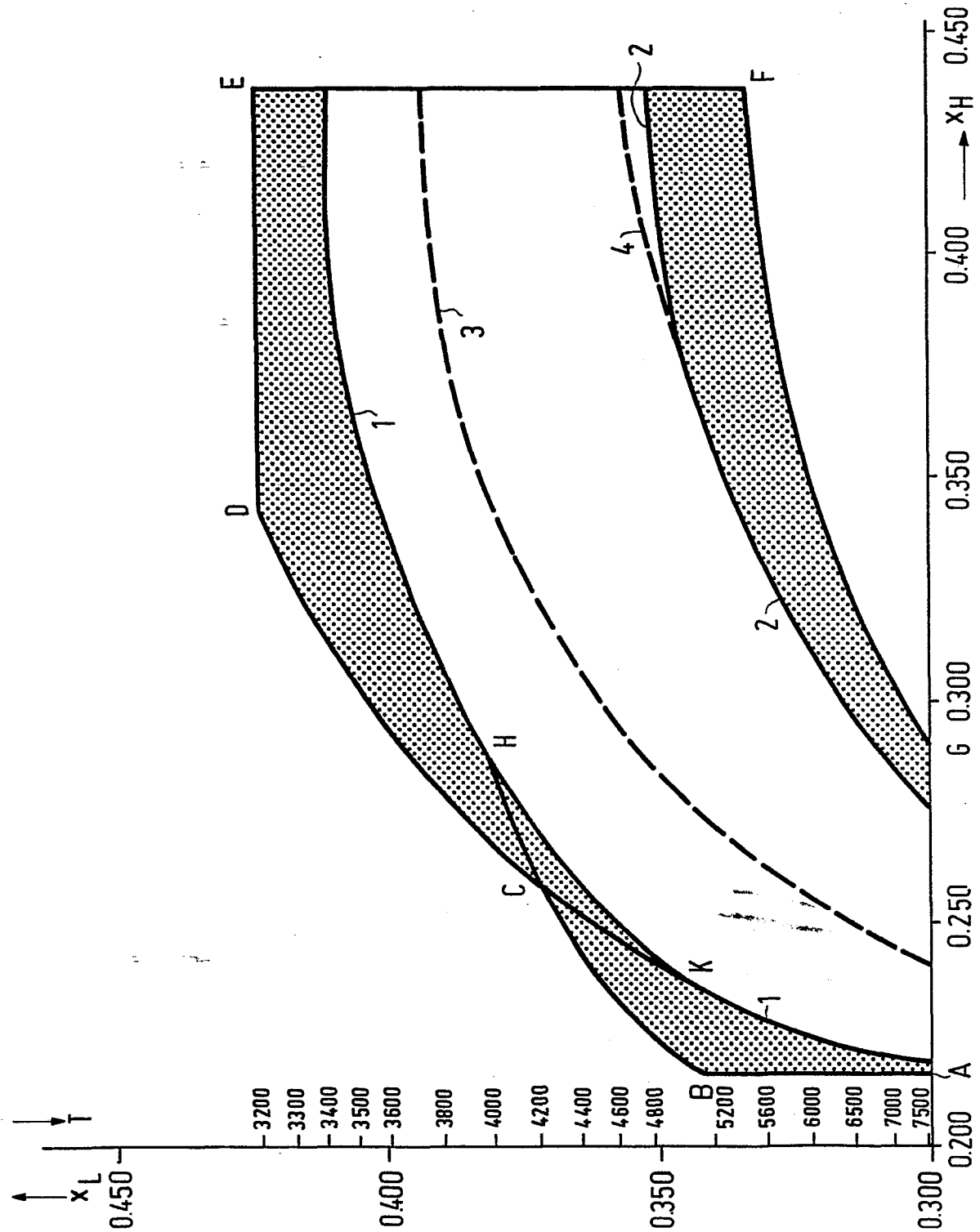
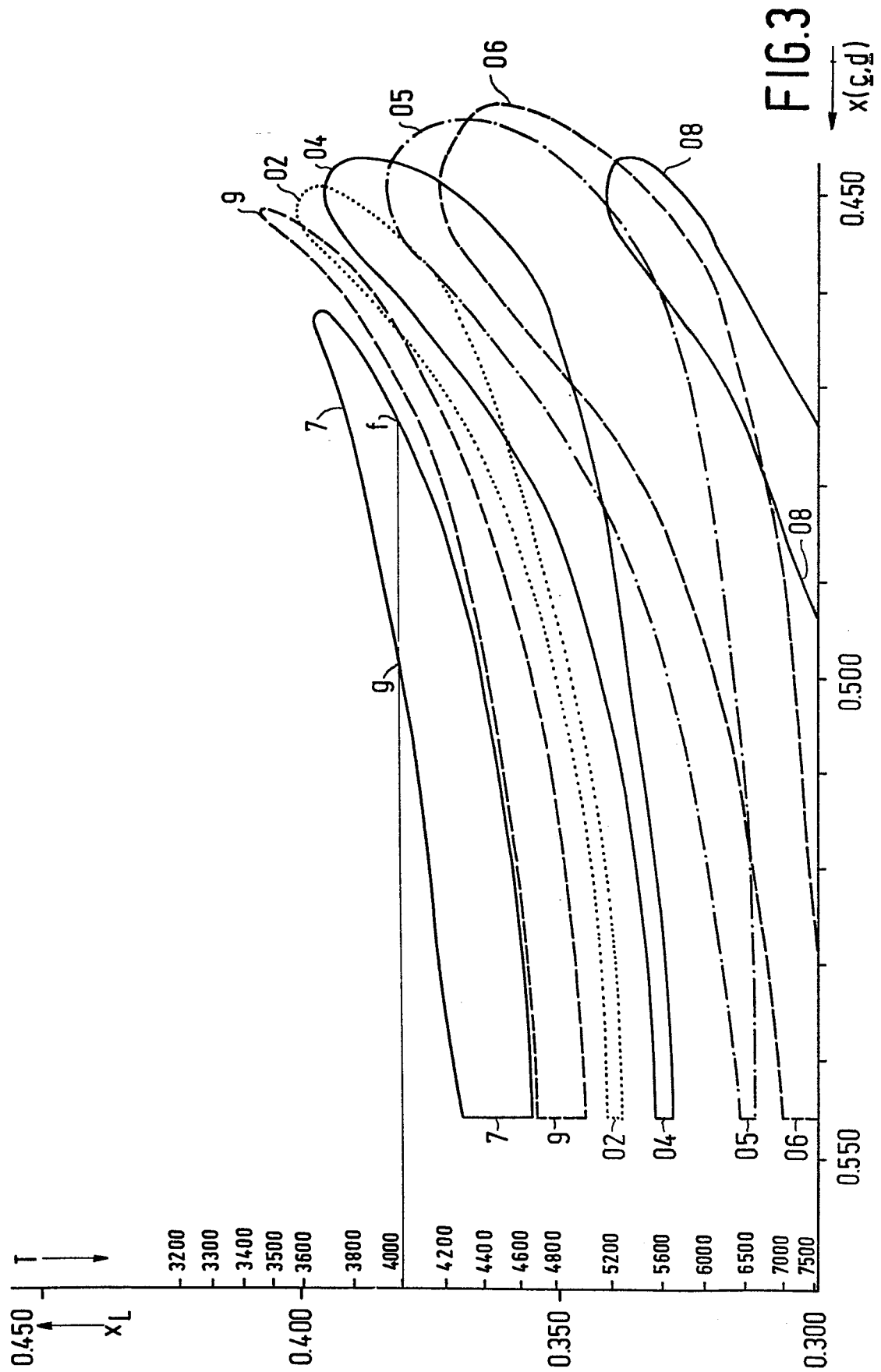
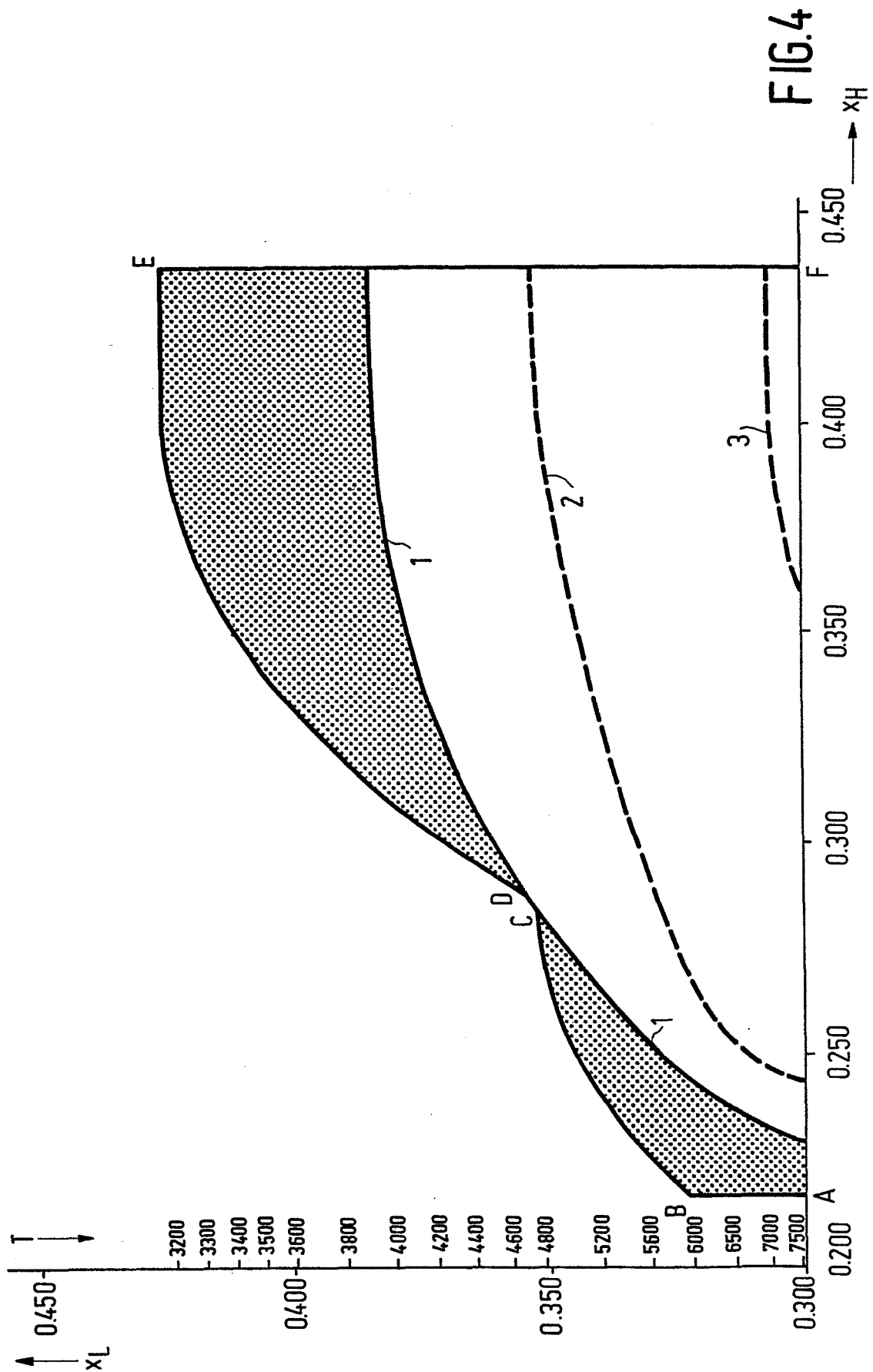


FIG. 1

FIG. 2







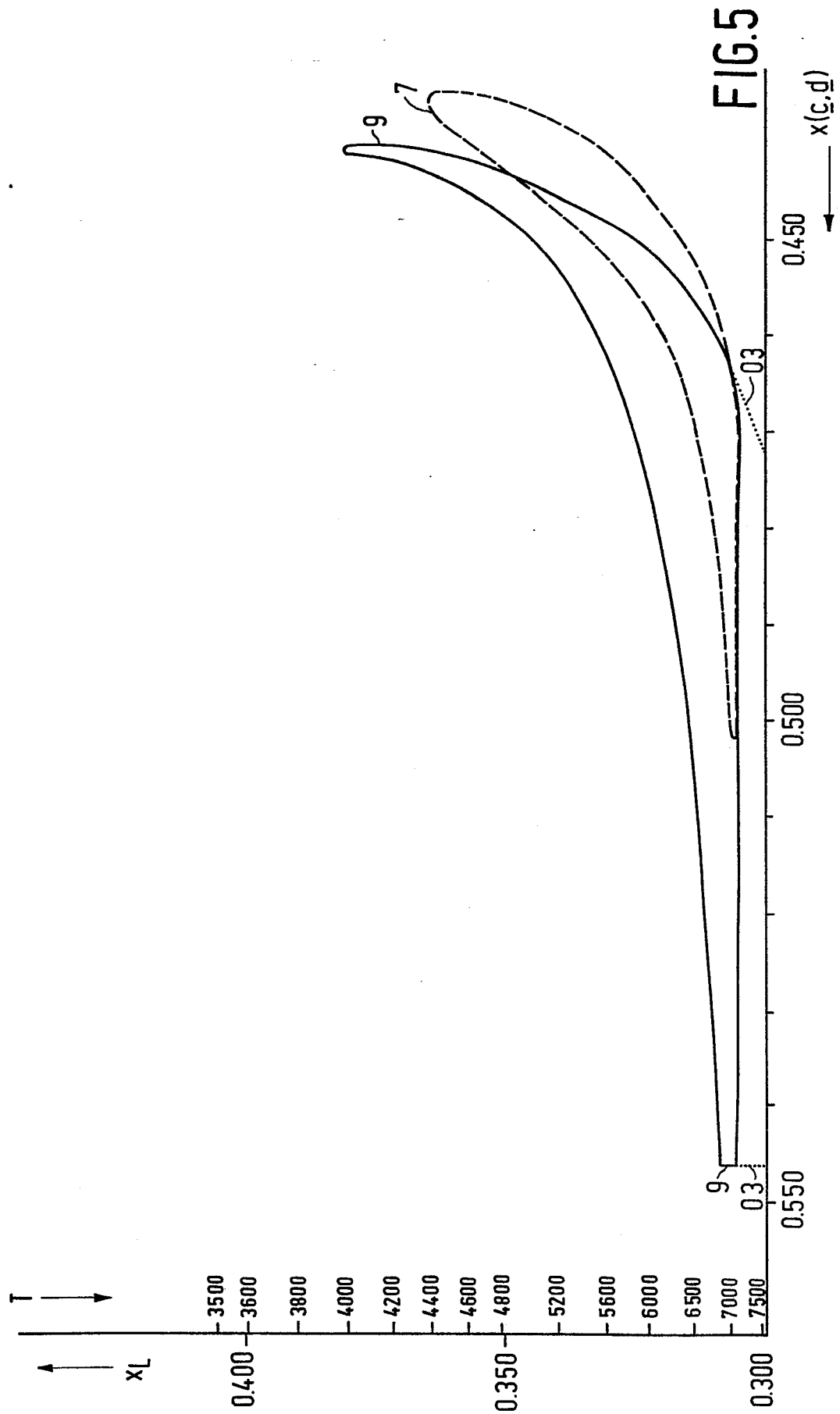


FIG. 6

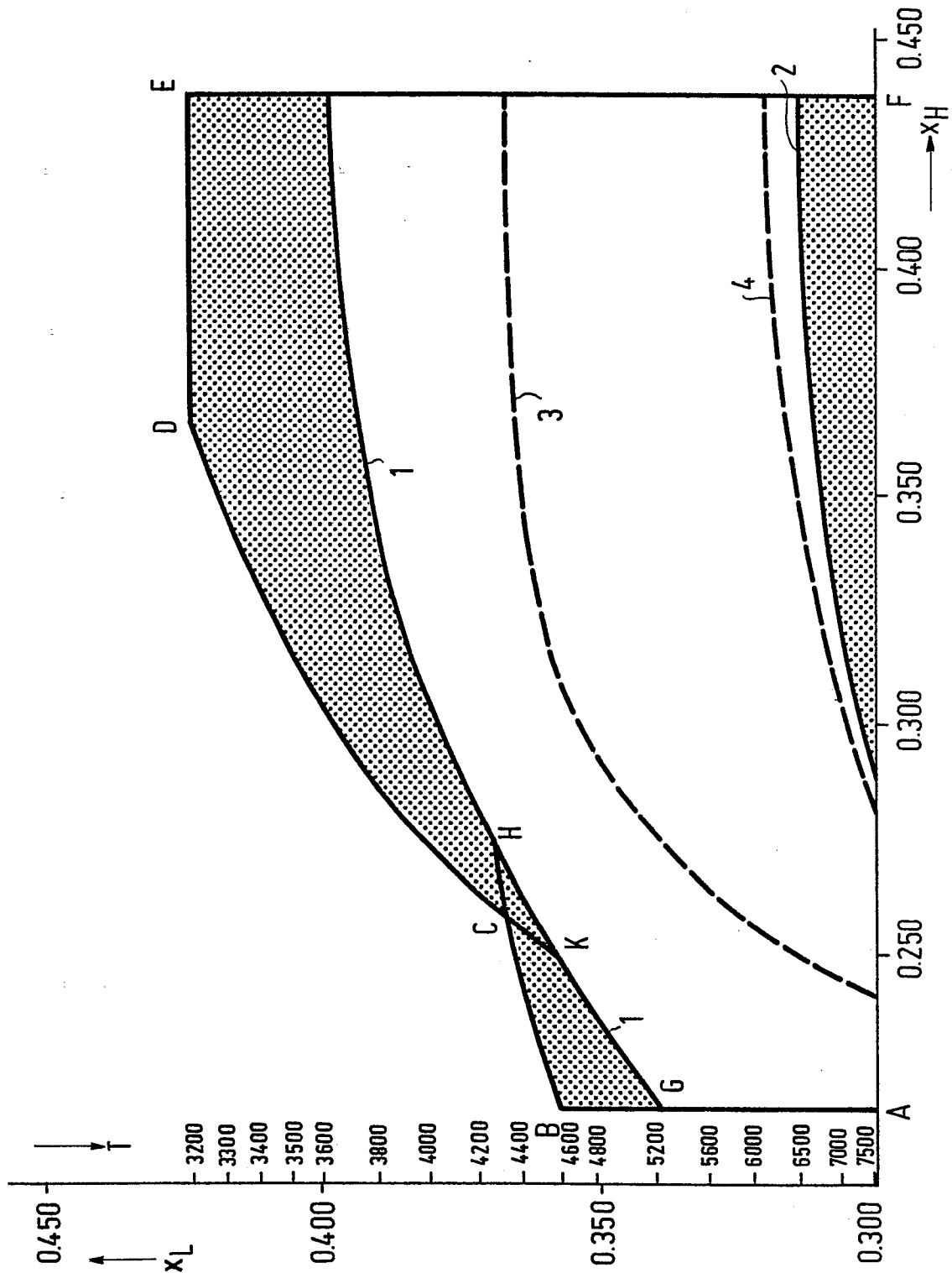
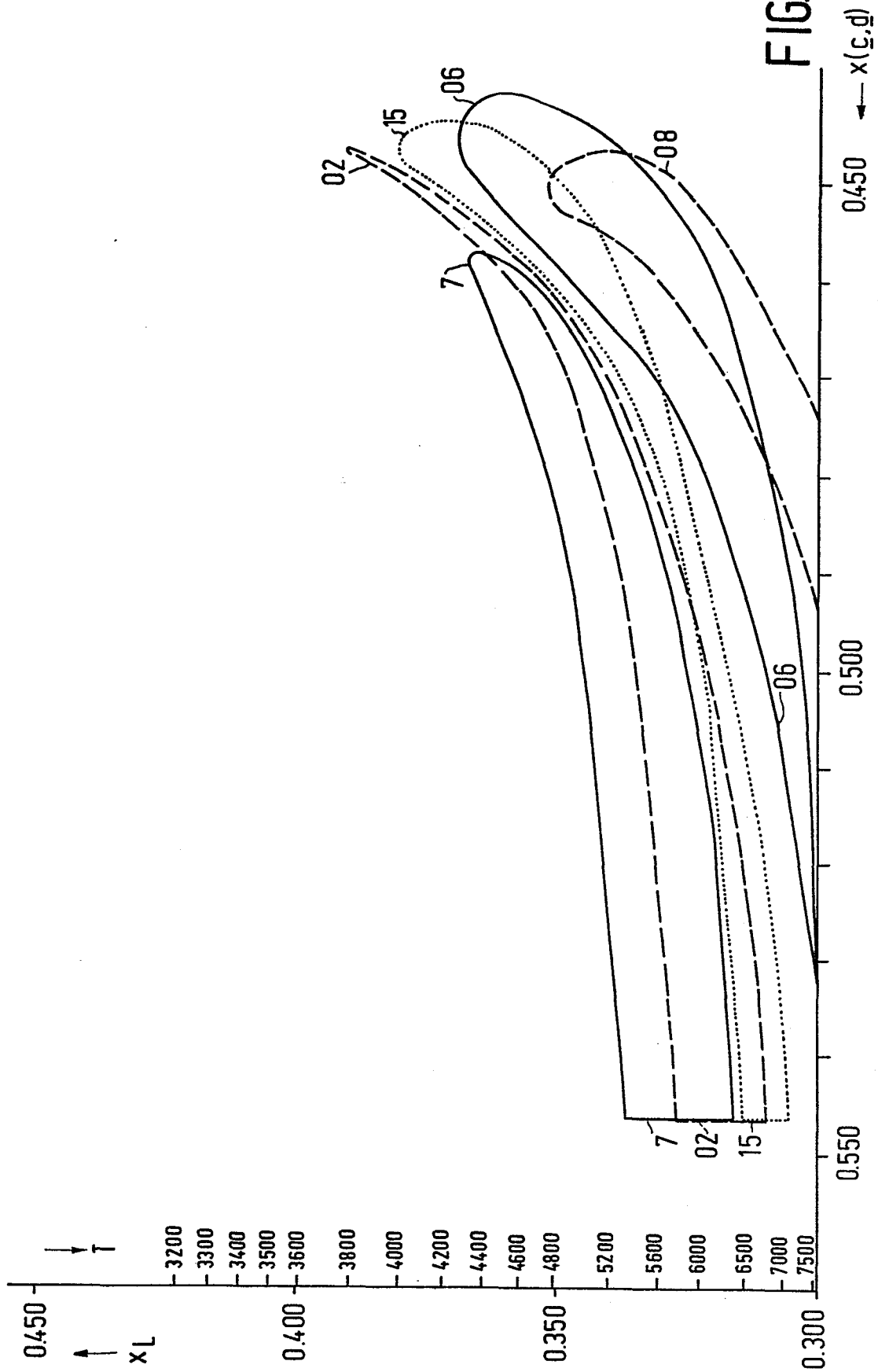


FIG. 7



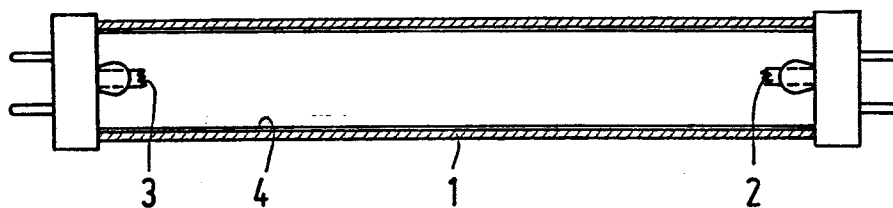


FIG.8

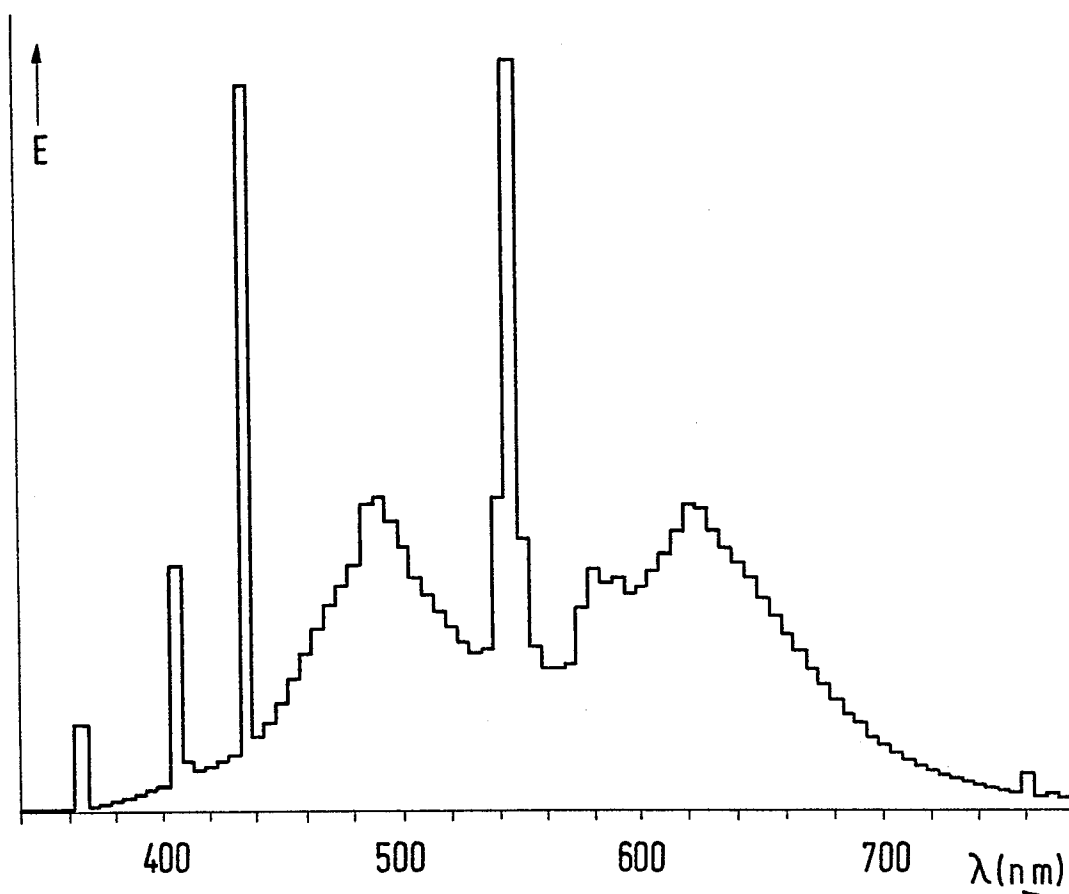


FIG.9



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	EP-A-0 023 068 (PHILIPS) * Claims 1-10 *	1,3,4	H 01 J 61/44 C 09 K 11/475
A,D	--- EP-A-0 057 026 (PHILIPS) * Claims 1-7 *	1,3,4	
P,X D	--- EP-A-0 082 570 (PHILIPS) * Claims 1-7 * -----	1,8	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
			H 01 J 61/00 C 09 K 11/00
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 04-04-1984	Examiner DROUOT M.C.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	